Trap Evaluations for Thrips (Thysanoptera: Thripidae) and Hoverflies (Diptera: Syrphidae)

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Environ. Entomol. 33(5): 1416–1420 (2004)

ABSTRACT Various trap types were evaluated for catching western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), and hoverflies (Diptera: Syrphidae). More western flower thrips were attracted to blue (458-nm peak reflectance) sticky card traps compared with yellow (560 nm) or white sticky card traps. Blue light-emitting diodes (LEDs; 465-nm peak emission) increased the efficacy of blue sticky card traps for catching western flower thrips. Numbers of western flower thrips caught on blue flat rectangular card traps were increased 2.0–2.5 times when cards were equipped with blue LEDs. Hoverflies adults are pollinators, and larvae are natural enemies of aphids and other pest insects. Hoverfly adults were attracted to blue sticky card traps. Nylon screen cages effectively excluded the hoverflies from the blue sticky card traps.

KEY WORDS thrips, hoverflies, traps, light-emitting diodes

WESTERN FLOWER THRIPS, *Frankliniella occidentalis* (Pergande), are serious pests of many greenhouse and field crops grown throughout the world (Tommasini and Maini 1995). Western flower thrip feeding causes discoloration and scarring of upper leaf surfaces or open blooms, petals, and fruits. Besides the feeding injury on host plants, western flower thrips are vectors of tomato spotted wilt virus (TSWV) (German et al. 1992, Wijkamp et al. 1995, Lowry et al. 1995). The TSWV/western flower thrips complex is of worldwide concern to the greenhouse industry (Broadbent and Allen 1995). Western flower thrips are sampled and monitored for different reasons: detection of the initial presence of western flower thrips, locating "hot spots" in the crop, predicting disease outbreak, determining the timing of control measures, and assessing the effectiveness of control measures (Shipp 1995). Because viruliferous western flower thrips can transmit TSWV so quickly, early detection is imperative (Robb and Parrella 1995). Sticky traps are commonly used to monitor western flower thrips (Shipp 1995).

Several thrips species are attracted to blue or white color. Blue was reported attractive to western flower thrips (Vernon and Gillespie 1990, Roditakis et al. 2001), *Thrips tabaci* Lindeman (Lu 1990), and *T. hawaiiensis* (Morgan) (Chiu and Wu 1993). White was reported attractive to western flower thrips (Yudin et al. 1987) and *T. palmi* Karny (Chu et al. 2000). Our preliminary observations indicated that western flower thrips are attracted to blue and yellow but not white.

Sticky cards and cups equipped with lime green (530-nm peak emission) light-emitting diodes (LEDs) catch more sweetpotato whiteflies, *Bemisia tabaci* (Gennadius) biotype B (=*B. argentifolii* Belows and Perring), greenhouse whiteflies, *Trialeurodes vaporariorum* (Weswood), and fungus gnats, *Bradysia coprophila* (Lintner), compared with unlit sticky card and cup traps (Chu et al. 2002, 2003a, b, Chen et al. 2004), but western flower thrips catches were not increased. The effects of blue LEDs on trap efficacy have not been reported.

In our preliminary western flower thrips trap experiments, large numbers of hoverflies (also called flower flies, syrphid flies, or drone flies; Diptera: Syrphidae) were caught on blue sticky card traps. Larvae of many hoverfly species are natural enemies of aphids and other pest insects (Clausen 1972, Gilbert 1993), and the adults are important pollinators (Sugiura 1996, Jarlan and Cingras 1997a, b, Lippok et al. 2000, Larson et al. 2001, Bernhardt et al. 2003). The capture of hoverflies by sticky cards not only reduces populations of these natural enemies but may also interfere with the capture of thrips by covering the sticky surface areas. Because hoverflies are much larger than thrips, we hypothesized that screens could be used to prevent the capture of hoverflies.

We report on western flower thrips catch efficacy of different colored sticky cards, the efficacy of blue sticky card traps equipped with blue LEDs, and the effect of nylon screens to exclude hoverflies from capture on sticky cards.

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Materials and Methods

Sticky Cards. Yellow and blue sticky card traps (7.6 by 12.7 cm) were purchased from Olson Products (Medina, OH). White sticky cards of the same dimensions were made at the laboratory and coated with Tanglefoot (aerosol formula; The Tanglefoot Co., Grand Rapids, MI). The light reflectance of the sticky cards was measured with a spectrometer (Full Range model; Analytical Spectral Devices, Boulder, CO). The peak wavelengths of the yellow and blue cards were 560 and 458 nm, respectively.

LEDs and LED Clip Attachments. Blue LEDs (peak emission, 465 nm; 2.5 lumen; 45° angle; NSPB320BS; Nichia America, Mountville, PA) used in the experiments were energized, each in series, with a 220-ohm resistor and powered via a 6-V direct current (DC) adaptor (Radio Shack, Fort Worth, TX). The adaptor was connected to a standard 110-V alternating current electricity source. One blue LED was wired to a 2.0-cm long piece of perforated circuit board. One circuit board with an LED was attached with screws to the tip of each arm of an 8.5-cm long hair clip (Goody Productions, Peachtree City, GA). The LED clips were attached to sticky cards with one LED on each side (see Chu et al. 2003b).

Experiment 1—Evaluation of Different Colored Sticky Card Traps. The experiment was conducted from 5 November to 10 December 2002 in a broccoli *Brassica oleracea* L. ('Marathon') field at Maricopa, AZ, in a randomized block design with three treatments and 10 replicates. Treatments were 7.6 by 12.7-cm blue, yellow, or white sticky card traps randomly set along a row and 180 cm apart. Rows were spaced 100 cm apart, and the plants were spaced 13–15 cm apart in a row. The plants were ≈10–15 cm high during the experimental period. The sticky cards were mounted vertically on wire stakes, and the bottom trap edges were ≈3 cm above the plant tops. The sticky cards were placed in every other row for a total of 10 rows (replicates). The sticky cards were retrieved after being covered by transparent plastic wraps, and new cards were replaced in the field weekly. In all experiments, western flower thrips and hoverflies caught were counted in laboratory with the aid of a stereomicroscope. The number of western flower thrips and hoverflies caught were analyzed using Friedman's nonparametric analysis of variance (ANOVA; PROC RANK and ANOVA; SAS Institute 2000). Means were separated using Tukey's test (significance level was $P = 0.05$).

Experiment 2—Evaluation of Blue Sticky Cards Equipped with Blue LEDs. The experimental design was paired treatments with eight replicates conducted from 28 February to 18 March 2003 in cages in a greenhouse. Treatments were blue sticky cards with or without blue LEDs. Eight wooden framed cages, each covered with 72-mesh screen and measuring 130 by 60 by 135 cm (length by width by height), were used in the experiment. Five pots of bloomingdale ranunculus, *Ranunculus asiaticus* L. (yellow and white flower type mix), were placed in each cage as host plants for western flower thrips. Western flower thrips were collected from a broccoli field in Maricopa, AZ, by shaking plants over a white tray and sucking with an aspirator. Approximately 50–60 western flower thrips were released into each cage daily during the experiment. Blue sticky cards with or without LEDs were placed in each cage and retrieved weekly. The bottom edges of sticky trap cards were ≈3 cm above plant tops. The numbers of western flower thrips caught were analyzed using a *t*-test (PROC TTEST; SAS Institute 2000). The significance level was $P = 0.05$.

Experiment 3—Evaluation of Caged Blue Sticky Card Traps. The experiment was conducted from 13 May to 17 June 2003 in a cotton ('Deltapine 5415') field at Maricopa, AZ, in a randomized block design with three treatments and six replicates. Two sizes of wood framed cages (10 by 2.5 by 14 and 10 by 1.3 by 14 cm in length, width, and height) covered with white nylon mesh screen were used (the area of each hexagonal cell was 16.2 mm^2) to prevent hoverflies from being caught on the blue sticky card traps. Treatments were uncaged blue sticky cards (trap C-0), blue sticky

Table 1. ***Frankliniella occidentalis* and *A. obliqua* (no./trap/wk ± SE) caught on blue, yellow, or white sticky card traps**

Trap week	Trap color	*Frankliniella occidentalis*/trap/wk	*F*	df	*P*	*Allograpta obliqua*/trap/wk	*F*	*P*
First	Blue	110.4 ± 11.9a[a]	16.55	11, 18	0.0001	2.4 ± 0.6a[a]	>100	0.0001
	Yellow	61.6 ± 6.5b				0 ± 0b		
	White	0.2 ± 0.1c				0 ± 0b		
Second	Blue	123.3 ± 11.8a	16.55	11, 18	0.0001	4.7 ± 1.0a	>100	0.0001
	Yellow	63.0 ± 5.0b				0 ± 0b		
	White	0.0 ± 0.0c				0 ± 0b		
Third	Blue	178.1 ± 33.7a	6.24	11, 18	0.0003	6.7 ± 1.9a	>100	0.0001
	Yellow	88.0 ± 16.3b				0 ± 0b		
	White	0.3 ± 0.2c				0 ± 0b		
Fourth	Blue	104.6 ± 13.7a	20.42	11, 17	0.0001	6.8 ± 1.4a	13.89	0.0001
	Yellow	33.8 ± 5.8b				0.2 ± 0.1b		
	White	0.0 ± 0.0c				0 ± 0b		
Fifth	Blue	321.6 ± 28.5a	>100	11, 18	0.0001	18.7 ± 2.4a	37.23	0.0001
	Yellow	98.4 ± 9.1b				2.1 ± 0.6b		
	White	0.2 ± 0.1c				0 ± 0b		

[a] Means in the same column followed by the different letters are significantly different at $P = 0.05$ (Tukey's test).

Table 2. *Frankliniella occidentalis* (no./card/wk ± SE) caught on blue sticky cards with or without LEDs

Trap week	Trap type	*Frankliniella occidentalis*/trap/wk	t	df	P
First	Card with LED	12.5.1 ± 1.2a[a]	4.98	14	0.0002
	Card without LED	5.1 ± 0.8b			
Second	Card with LED	7.6 ± 1.1a	3.92	14	0.0015
	Card without LED	3.0 ± 0.5b			
Third	Card with LED	12.8 ± 1.4a	3.47	14	0.0037
	Card without LED	6.5 ± 1.1b			
Fourth	Card with LED	7.6 ± 0.6a	5.18	14	0.0001
	Card without LED	3.8 ± 0.5b			

[a] Means in the same column followed by the different letters are significantly different at $P = 0.05$ (t-test).

cards equipped with 2.5-cm-wide cages (trap C-2.5), or blue sticky cards equipped with 1.3-cm-wide cages (trap C-1.3). Rows were spaced 100 cm apart, and the plants were spaced 15 cm apart. The plants were ≈25–50 cm high during the experiment. Each uncaged or caged sticky card trap was randomly set 180 cm apart along a cotton row. The traps were mounted vertically on wire stakes, and the trap bottom edges were ≈3 cm above plant tops. Trap treatment replicates were set in every other row for six rows. The blue sticky cards were retrieved, and new ones were replaced in the field weekly. The numbers of hoverflies caught were analyzed using Friedman's nonparametric ANOVA (PROC RANK and ANOVA; SAS Institute 2000). Means were separated using Tukey's test (significance level was $P = 0.05$).

Results and Discussion

Experiment 1. Thrips caught on traps in all experiments were mainly western flower thrips, although several other species were observed on occasion (identification reference: Laurence and Kibby 1998). Higher numbers of western flower thrips were caught on blue sticky card traps compared with yellow or white sticky card traps (Table 1). Blue sticky cards caught 104.6–321.6 thrips weekly compared with 33.8–98.4 caught on yellow and 0–0.2 caught on white cards, indicating that blue was the best trap color for western flower thrips, white was the least attractive, and yellow was intermediate in attractiveness. The blue preference of western flower thrips agrees with previous reports (Lu 1990, Vernon and Gillespie 1990, Chiu and Wu 1993, Roditakis et al. 2001). The nonpreference of western flower thrips to white color also agrees with the report of Mateus and Mexia (1995), but differs from the report by Yudin et al. (1987).

However, hoverflies were also caught on blue sticky card traps. Most of them were *Allograpta obliqua* (Say) (identification references: Butler and Werner 1957, Vockeroth 1992). Numbers of *A. oblique* caught on blue sticky card traps ranged from 2.4 to 18.7 per trap per week compared with 0.0–2.1 on yellow and 0.0 on white sticky card traps (Table 1). Hoback et al. (1999) also reported that some hoverflies (species unidentified) were attracted to blue traps. *A. obliqua* has been reported as a predator of several species of aphids (Davidson 1916, Curran 1920, Thompson 1928, Butler and Werner 1957), as well as iris whitefly *Alyrodes spiraeoides* Quaintance and sweetpotato whitefly (Resendiz-Ruiz 1993). *A. obliqua* is widely distributed throughout Arizona (Butler and Werner 1957).

Experiment 2. Blue sticky card-LED–equipped traps caught significantly more western flower thrips than blue sticky card traps alone (Table 2). Over the

Table 3. Hoverflies (no./card/wk) caught on caged and uncaged blue sticky card traps

Trap week	Trap type[a]	*Allograpta obliqua*/trap/wk	F	df	P	Total/trap/wk[b]	F	P
First	C-0	3.5 ± 0.3a[c]	>100	7, 10	0.0001	4.3 ± 0.4a[c]	>100	0.0001
	C-1.3	0b			0b			
	C-2.5	0b			0b			
Second	C-0	2.5 ± 0.6a	>100	7, 10	0.0001	2.8 ± 0.2a	>100	0.0001
	C-1.3	0b			0b			
	C-2.5	0b			0b			
Third	C-0	1.3 ± 0.2a	>100	7, 10	0.0001	2.0 ± 0.3a	>100	0.0001
	C-1.3	0b			0b			
	C-2.5	0b			0b			
Fourth	C-0	1.2 ± 0.2a	>100	7, 9	0.0001	2.2 ± 0.4a	>100	0.0001
	C-1.3	0b			0b			
	C-2.5	0b			0b			

[a] C-0, uncaged blue sticky cards; C-1.3, blue sticky cards equipped with 10 by 1.3 by 14-cm cages; C-2.5, blue sticky cards equipped with 10 by 2.5 by 14-cm cages.
[b] Total species of hoverflies.
[c] Means in the same column followed by the different letters are significantly different at $P = 0.05$ (Tukey's test).

4 wk of the experiment, the average numbers of thrips caught on blue sticky card-LED traps ranged from 7.6 to 12.8 per card per week compared with 3.0–6.5 per card per week for the blue sticky card trap alone. The blue LEDs increased the western flower thrips catches of blue sticky cards by 2.0–2.5 times. Results suggest that the blue LED equipped sticky traps may be useful in greenhouses for monitoring and reducing thrips numbers.

Experiment 3. Although the hoverfly population was low at the time of our experiment, the capture differences between the caged and uncaged blue sticky card traps were highly significant (Table 3). The total numbers of hoverflies caught on uncaged blue sticky cards ranged from 2.0 to 4.3 per card per week over the 4-wk experimental period. No hoverflies were captured on caged blue sticky cards. The mesh screen effectively excluded the hoverflies from capture. This may be important because hoverflies are beneficial insects in both the immature and adult stages. The pollinating effects of some hoverflies have been assessed. For example, according to Jarlan and Cingras (1997a, b), hoverfly *Eristalis tenax* L. is a pollinator of greenhouse sweet pepper, and the fruits from fly-visited groups produced larger seed sets (augmentation of 9.2–19.3%) and fruit pericarp circumference (increased by 5%) compared with those from the nonvisited group. Predaceous hoverfly larvae attack aphids and other pests in several families: Aleyrodidae, Chermidae, Coccidae, Ceropidae, and lepidopterous larvae (Clausen 1972, Resendiz-Ruiz 1993). Each larva can eat up to 1,200 aphids during the course of development (Gilbert 1993). The cages in our experiments were made from wood and nylon screen and were inexpensive. It may be worthwhile to use the cages to exclude the hoverflies from the capture when monitoring western flower thrips with blue sticky traps.

Acknowledgments

We thank O. Isensee, S. Tuck, and M. Luckitt for assistance in this study. We appreciate the constructive review of the earlier version of the manuscript by J. Byers and T.-X. Liu. We also thank three anonymous reviews for critical comments.

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Received 16 December 2003; accepted 28 June 2004.